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ANNUAL STATUS REPORT
(Millimeter Wavelength Propagation Studies)
November, 1972 through October, 1973

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ANNUAL STATUS REPORT 2374-17

October 1973

Grant Number NGR 36-008-080

National Aeronautics and Space Administration
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ABSTRACT

This status report describes the recent progress of the Millimeter-Wavelengths Propagation Studies conducted under NASA Grant No. NGR 36-008-080. The Ohio State University High Resolution Radar/Radiometer System and the Low Resolution Radar System both became operational during this time period.

The Ohio State University diversity data obtained using the ATS-5 satellite and available BTL data have been compared with optimum diversity gain predictions. This comparison indicates that terminal spacings exceeding 8 km result in values of diversity gain within 1.5 dB of the optimum. The thunderstorm cell modeling technique for predicting attenuation and diversity gain statistics has been extended to include ellipsoidal cell models. A three rain gauge method for the measurement of cell size, ellipticity, and orientation has been developed.

Initial preparations for the 20 and 30 GHz ATS-F Millimeter Wave Experiment and the 13 and 18 GHz ATS-F Propagation Experiment have begun.

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INTRODUCTION

During the past year the efforts under NASA Grant No. NGR 36-008-080 entitled "Millimeter-Wavelengths Propagation Studies" have been concentrated in three areas. These areas are: radar and radiometer measurement of thunderstorm cell characteristics; the analysis, interpretation, and prediction of diversity statistics; and preparations for the ATS-F Millimeter Wave and Propagation Experiments. The progress in these areas is summarized in the following.

A complete list of reports, oral presentations, and papers generated to date under this grant has been included in the Reference section of this report.

MEASUREMENT OF THUNDERSTORM CELL CHARACTERISTICS

Both the High Resolution Radar/Radiometer System and the Low Resolution Radar System became operational during the current time period. These systems are described in Reference [19]; they provide the capability of simultaneous measurement of radar backscatter and radiometric noise emission at 3, 9, and 15 GHz using the High Resolution System. Radar backscatter is also measured at 9 GHz using the Low Resolution System. Thus, the frequency dependence of the backscatter noise emission, and, indirectly, attenuation may be determined. And, in addition, the three-dimensional spatial and temporal structures of thunderstorm cells may be examined in detail.

Data gathering by these systems is under way and initial data processing programs have been completed. The data acquisition and data processing will continue through the remainder of 1973 and early 1974 in an effort to gain the maximum experience and data base with these systems prior to the launch of ATS-F. These systems will be operated concurrently with the ATS-F experiments described later in this report.

DIVERSITY STATISTICS

A thorough study of the available diversity statistics for earth-space links operating above 10 GHz has been completed. These data include the attenuation measurements obtained by Ohio State University using the ATS-5 15 GHz link and the radiometric measurements made by the Bell Telephone Laboratories. A total of eight experiments having terminal separations ranging from 3 to 31 km were examined. In all cases the terminal baselines were oriented in approximately NW-SE directions, the frequencies were approximately 15 GHz, and the elevation angles of the propagation paths were approximately 35°.

When analyzed in terms of the resulting diversity gain, the results of the various experiments were found to be remarkably consistent. This analysis clearly indicates that little additional diversity advantage is gained for terminal separations exceeding 8 km. In fact, it can be shown that the diversity gain resulting from a terminal separation of 8 km is within 1.5 dB of the maximum achievable diversity gain. Furthermore, these data indicate that multiple cell effects, i.e., the occurrence of different cells on the separated propagation paths, are not significant. These results, as well as the treatment of the optimum or maximum achievable diversity gain, are discussed in Reference [25].

The theoretical technique for the prediction of attenuation and diversity gain statistics described in Reference [16] has been generalized to permit the analysis of ellipsoidal thunderstorm cells. This generalization allows four degrees of freedom; cell length, width, height, and orientation, in the modeling of the cell. Some preliminary results of this effort are discussed in Reference [25].

The modeling of thunderstorm cells by ellipsoids has emphasized the severe lack of detailed statistics concerning thunderstorm cell size and shape. Thus, a simple and inexpensive technique has been developed for the determination of effective cell lengths, widths, and orientations. This method utilizes only three rain gauges located along perpendicular lines at spacings of about 0.5 km. This procedure could be implemented quite simply in regions where high resolution radar data are not available. This technique is described in Reference [23].

ATS-F EXPERIMENTS

The initial preparations for the ATS-F Millimeter Wave and Propagation Experiments have begun. The Ohio State University participation in the ATS-F Millimeter Wave Experiment will include the measurement of down-link attenuation at 20 and 30 GHz on two separated propagation paths, the measurement of radiometric noise emission at 30 GHz along the same paths, and the measurement of radiometric noise emission at 20 GHz along three paths two of which are identical to those used for the attenuation measurements. Both the High Resolution Radar/Radiometer System and the Low Resolution Radar System will be operated during this experiment to observe the radar backscatter and radiometric noise emission at 3, 9 and 15 GHz along the remote propagation paths.

Ohio State University is also cooperating with COM-SAT in the establishment and operations of four up-link terminals at 18 GHz and one up-link terminal at 12 GHz in conjunction with the ATS-F Propagation Experiment. These experiments will provide comprehensive attenuation and diversity gain statistics at frequencies ranging from 12 to 30 GHz and at a variety of terminal separation distances and orientations.

The Ohio State University Transportable Terminal has been moved back to our Laboratory and has been prepared for outfitting with the required equipment for this experiment. As noted earlier in this report, both the High Resolution Radar/Radiometer System and the Low Resolution Radar System are now operational and are currently being operated to establish a data base for this experiment. Finally, OSU has provided assistance to COM-SAT in the establishment of site locations for the four up-link terminals.

SUMMARY

The progress of both experimental and theoretical efforts under NASA Grant No. NGR 36-008-080 have been described. These efforts include the development of a High Resolution Radar/Radiometer System and a Low Resolution Radar System for the measurement of thunderstorm cell characteristics; the analysis, interpretation, and prediction of diversity statistics; and the initial preparations for the ATS-F Millimeter Wave and Propagation Experiments.

REFERENCES

Note: This reference list includes all reports, oral presentations, and papers generated under NASA Grant No. NGR 36-008-080.

1. Semiannual Status Report, "Proposed Experiment for Measurement of Amplitude and Phase Decorrelation," Report 2374-1, June 1967.

2. Annual Status Report, "Millimeter-Wavelengths Propagation Studies," Report 2374-2, November 1969.

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5. Bohley, P. and Hodge, D.B., "A Millimeter Wave Diversity Propagation Experiment," presented at the Fall 1970 URSI Meeting, Columbus, Ohio, September 1970.

6. Semiannual Status Report, "Millimeter-Wavelengths Propagation Studies," Report 2374-5, October 1970.

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8. Semiannual Status Report, "Millimeter-Wavelengths Propagation Studies," Report 2374-6, June 1971.

9. Grimm, K.R. and Hodge, D.B., "A 15.3 GHz Satellite-to-Ground Diversity Propagation Experiment Using a Terminal Separation of 4 Kilometers," Report 2374-7, December 1971.

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11. Zintsmaster, L.R., "The Estimation of Attenuation Statistics for Earth-Space Millimeter Wavelength Propagation," presented at the Spring 1972 URSI Meeting, Washington, D.C., April 1972.

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13. Hodge, D.B. and Zintsmaster, L.R., Semiannual Status Report, "Millimeter-Wavelengths Propagation Studies," Report 2374-9, May 1972.

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16. Zintsmaster, L.R. and Hodge, D.B., "The Prediction of Millimeter Wavelength Precipitation Attenuation Using a Cylindrical Storm Cell Model," Report 2374-10, June 1972.

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18. Hodge, D.B., Semiannual Status Report, "Millimeter-Wavelengths Propagation Studies," Report 2374-12, December 1972.

19. Hodge, D.B. and Taylor, R.C., "The Ohio State University Electro-Science Laboratory Radar/Radiometer Facilities for Precipitation Measurements," Report 2374-13, March 1973.

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21. Zintsmaster, L.R., Technical Memorandum, "Low Resolution Radar Digital Interface," Report 2374-14, May 1973.

22. Hodge, D.B., "A Simple Method for Determining Effective Rain Cell Diameters," presented at the 1973 USNC/URSI Meeting, Boulder, Colorado, August 1973.

23. Hodge, D.B., "A Simple Method for the Determination of Effective Rain Cell Dimensions and Orientation," Report 2374-15, September 1973.

24. Hodge, D.B., "Space Diversity for Reception of Satellite Signals," accepted for presentation at IUCRM Colloquium on "The Fine Scale Structure of Precipitation and EM Propagation," Nice, France, October 1973.

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